IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

A REVIEW OF HEAVY OIL PROPERTIES AND TRANSPORTATION METHODS FOR HEAVY CRUDE OIL AND BITUMEN VIA PIPELINE

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Abstract: Heavy oil comprises of 75% of petroleum resources in the world. Only a small fraction of these resources have been produced due to crucial and expensive techniques than those of the conventional oils. Due to the decline in the production of easy oil, industries are striving hard for utilizing unconventional oil resources which consists of mainly heavy oils, extra heavy oils and bitumen.These resources consists of viscous oils so their use requires extra efforts to ensure the viability of the oil recovery from the reservoir and its subsequent transportation to production wells and to ports and refineries. For satisfying the demand of the market the oil companies need to improve the efficiency of upstream, midstream and downstream. The paper mentions the challenges faced by the oil companies during production and transportation. Different technologies are reviewed and the benefits and constraints of each technology are highlighted with the view that this will provide direction for improvement and development of novel technologies for heavy oil transportation via pipelines. The main properties of heavy crude oils like high viscosity, density, etc as well as traditional and emergent methods for their recovery and transportation are discussed. The challenges to achieve viable recovery and transportation of unconventional oils are compared for the different alternatives purpose. The work specifically focuses on the heavy oils, its properties, efficient methods of recovery and transportation. If the challenges mentioned in the review are handled properly than there is a significant potential for the upcoming innovative projects to become economically flexible.

***Index Terms* – Heavy oil, bitumen, transportation**

I. INTRODUCTION

Heavy oil represent a major portion of the world's unproduced oil. It is highly viscous oil that cannot flow easily to the production well under normal reservoir conditions. Due to its high density and viscosity at normal atmospheric conditions production methods are energy demanding as compared to other lighter crude oils, traditionally. They are attributed 'heavy' due to density and specific gravity which is higher than lighter crude oils. It has an API gravity less than 20^o. Physical properties like viscosity, specific gravity as well as heavier molecular composition vary from other crudes. Heavy oil is related to bitumen from oil sand which is the heaviest form of petroleum. Heavy oil and Bitumen obtained from crude differ from light oils in their characteristics. Due to this reason the recovery of heavy oil differ from the conventional oil. Heavy crudes require abundant energy source for production. Its production cost due to different technology involved is quite high as compared to conventional oil.

World Reserves

The petroleum reserves in the world are extremely challenging. Out of the world's total oil reserves, heavy oil, extra heavy oil and Bitumen make up almost 70% of the reserves. This emphasize to increase the efforts for heavy oil production as the supplies of conventional oil are decreasing. Heavy oil is particularly found in supergiant and shallow deposits. Fig.1 show the distribution of oil reserves in world.

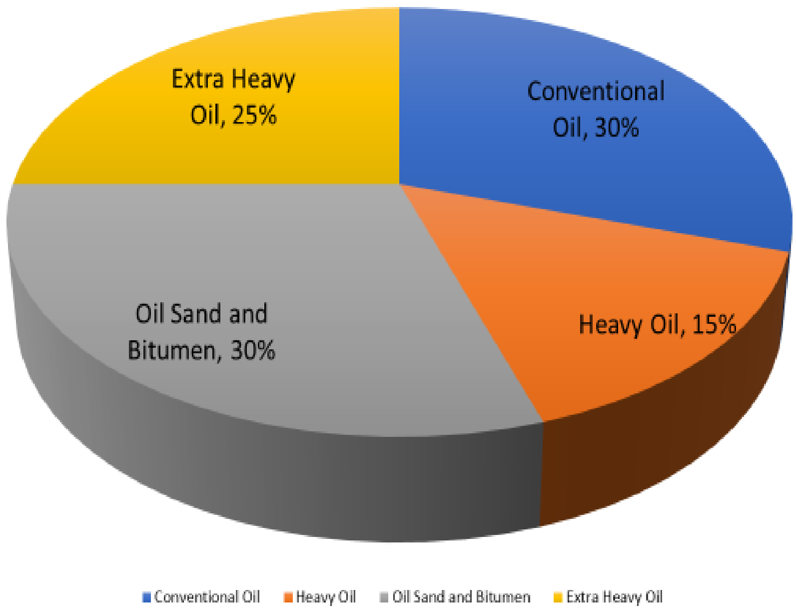

Figure 1: Distribution of total oil reserves in world

II. DISCUSSION

2.1 Classification

Heavy oil, extra heavy oil, oil sand, tar sands, oil shale and bitumen are all unconventional oil resources. Confusing heterogeneous denominations arise because of similar key characteristics presented by these resources. The classification of oil is expounded to the crude oil's easy flow which shows the characteristics of their production, transportation and refining. Oil companies and government agencies usually adopt oil definition criteria that take into account financial aspects and the degree of technological improvement. As a large variety is seen in them, these criteria have limited applications. In refineries and oil fields, the criteria adopted are generally related to crude oil properties, such as density and viscosity.

The most widely used definition for heavy oils relies on the API gravity proposed by the American Petroleum Institute, which uses the ^{o}API scale (index that is based on the oil relative density) because the criterion for oil classification. The API degree range is to define and classify oils has not been standardized. For instance, the planet Petroleum Conference classifies heavy oil as those having below 22.3 API degrees. For the American Petroleum Institute, heavy oil is defined as those having an API index equal to or smaller than 20 degrees. The North American taxation system has a similar criterion. Based on the API index, the Brazilian National Petroleum Agency (ANP) identifies four different types of petroleum, as shown in Table 1.

Table 1: Crude oil classification by National Petroleum Agency of Brazil

Oil Class	ºAPI
Light	ºAPI≥31
Medium	22≤ºAPI<31
Heavy	10º≤API<22
Extra-heavy/Natural bitumen	ºAPI≤10

It is categorized by low API and high viscosity values. Heavy oil have API gravity between 10º - 20º. Oils heavier than 10º are known as extra heavy oils / natural bitumen. Viscosity strongly affected by temperature fluctuation in heavy crude oils. Thus, thermal recovery methods are commonly used in heavy oil production. Density and Viscosity are the key characteristics that determine the economy of heavy oil field development. Fig.2 shows graphical representation of density and viscosity of heavy oils. Heavy oil is generally sold at lower prices compared to that of lighter oil, due to additional energy intensive upgradation before its use. Higher viscosity values also affect the production values. Oil turn viscous when its density increases. It is due to presence of asphaltenes that tends to aggregate. Oil viscosity increases exponentially with asphaltene content.

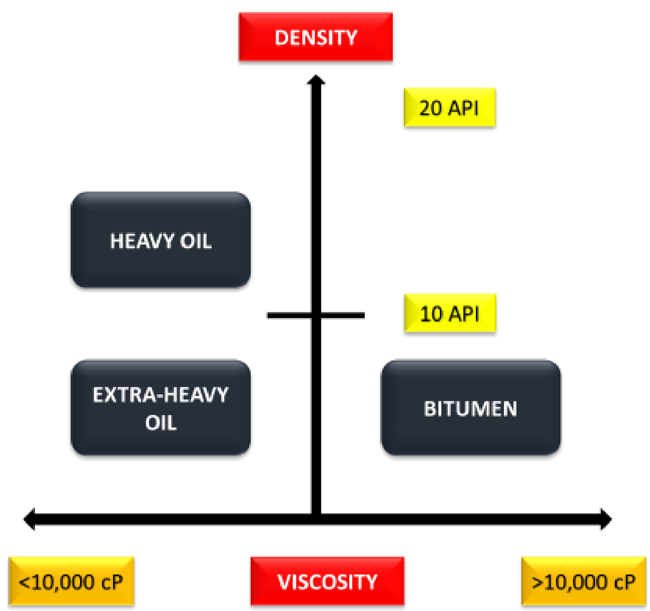

Figure 2: Graphical representation of density and viscosity of heavy oils

2.2 Generation

The particular characteristics of the heavy oils are mainly attributed to a biodegradation process in which microorganisms on a geological time scale degrade light and medium hydrocarbons, making the reserves rich in polyaromatic compounds, resins and asphaltenes. Microbial degradation reaches optimal temperatures below 80 ºC, promoting oil oxidation, reduction of the gas/oil ratio (GOR) and increasing density, acidity, and viscosity as well as the relative proportion of sulfur and heavy metals. Besides biodegradation, heavy oil formation can occur through mechanisms such as water washing and phase fractionation, which are based on the loss of a significant fraction of original mass, and removal of light petroleum fractions by physical rather than biological means. Heavy oils usually occur in giant shallow formations in marginal geological basins formed by non-consolidated sand. Heavy oil reservoirs have low pressure and low gas/oil ratio, resulting in lower recovery factors in comparison to light oil reservoirs. Although the characteristics of the heavy oil reservoirs have more complex and expensive production processes, factors such as high permeability can make the process worthwhile.

III. Extraction Technology

Due to high density and viscosity of heavy oil, efficient methods for recovery of heavy oil are used. The methods generally used are Cold Production, Surface Mining and Thermal Recovery Method.

3.1 Cold Production:

It is a method in which oil is produced through a borehole without applying heat, resembles to the conventional oil recovery methods. It is applied to the oil having viscosity below 1000cP at standard conditions or when the temperature of reservoir is high which mobilizes the oil. The well performance is boosted by diluents or artificial lifts. The bottom hole pressure in the well is allowed to drop the minimum criteria so that sand production is prevented. The removal of sand around the wellbore creates channels in formation, boosts the production by creating high permeability. This method requires advanced pumps which can hold huge amount of solids. The recovery factor by this method is fairly low.

3.2 Surface Mining:

It is a common recovery method used for bitumen. It is used when bitumen is located on very shallow layers over a large area, which makes it an economically affordable borehole for production. The oil sands are recovered and transported manually by shovels and trucks. This method may recover 60-70% of hydrocarbon, but it adversely affects the environment.

3.3 Thermal Methods:

CSS – Cyclic Steam Stimulation

CSS is the Cyclic Steam Stimulation which is a single-well process where the well is alternately acting as an injector and a producer. Steam injection is applied on stages. First of all steam is injected for a particular time span. Then, injection is halted and the reservoir is allowed to absorb the heat from the steam. After the soaking period, the well is set to produce. This cycle is repeated for as long as the well is profitable.

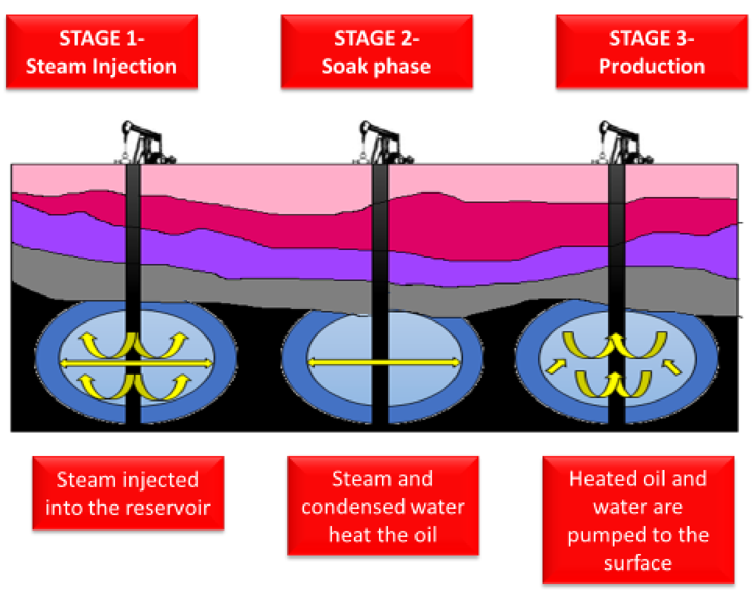

Figure 3: The CSS process

Steamflooding

This is a multi-well pattern process where injection and production run continuously. The steam injectors provide pressure drives and by constant heating the viscosity is lowered. The optimum well pattern varies between fields. The method is economically costly due to the high amount of energy to be provided through the steam injectors but the recovery factors are up to 50%. The steam injection can determine the success ratio of the method. High steam injections may cause an early steam breakthrough, while a low rate will lead to excessive heat losses.

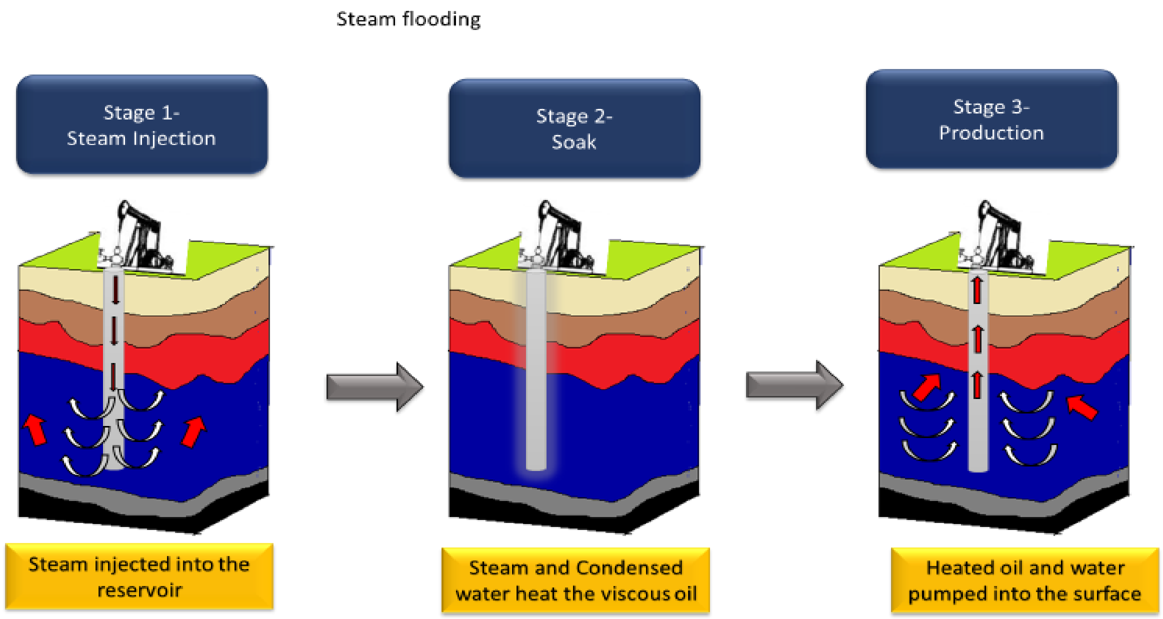

Figure 4: Steamflooding

SAGD – Steam-Assisted Gravity Drainage

In this method, two parallel horizontal wells are drilled in the lower section of the formation. Heated oil and water is produced from the lower well while steam is injected in the upper well. A steam chamber gradually grows above the well pair as the steam rises into the formation, and the oil is heated at the interfacial layer of the steam chamber. This method is observed to be effective for highly viscous oils but recovery factors are highly sensitive to geology.

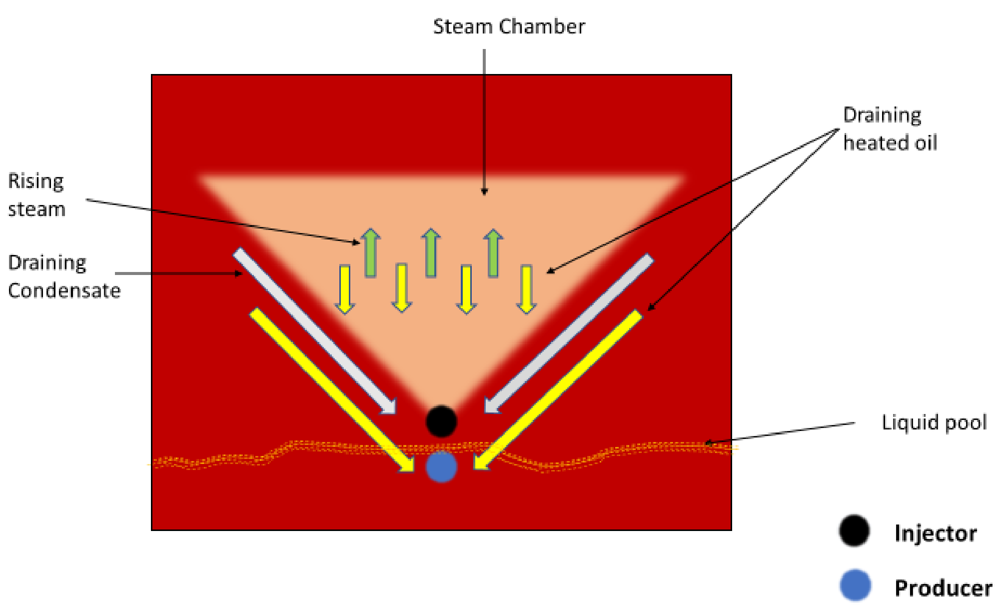

Figure 5: SAGD Concept

IV. Heavy Oil Production Technology

4.1 Pipeline Transport

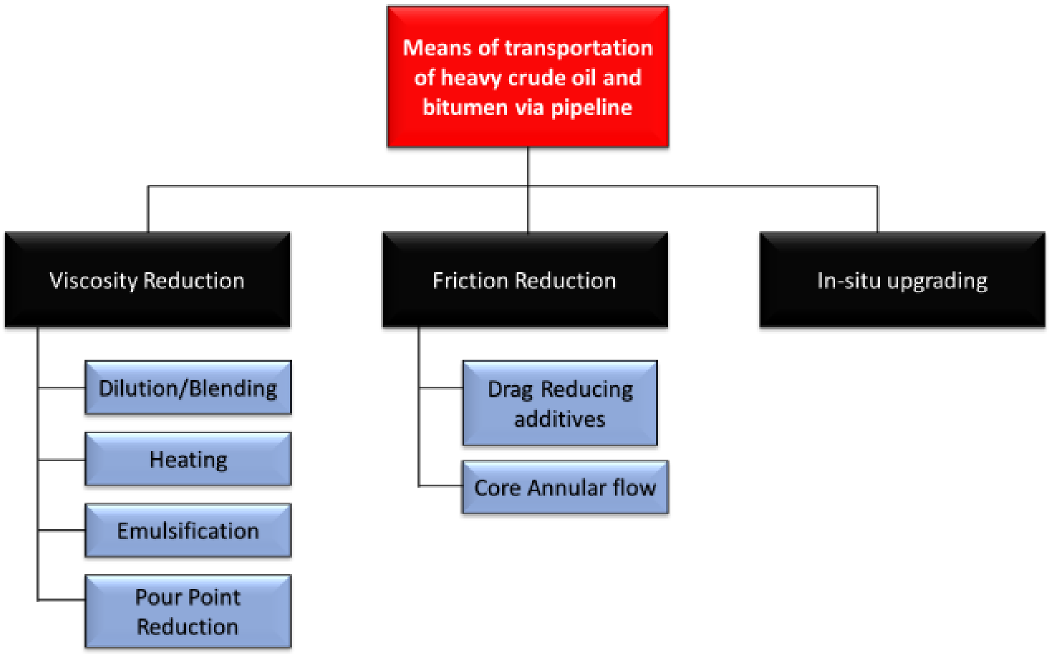

Figure 6: Diagrammatic display of methods of improving heavy crude oil and bitumen flow via pipelines

For transportation of heavy oils economically, the pressure drops by the pipeline must be lowered to minimise the pump power required to push the oil over an extended distance. Due to high viscosity at reservoir conditions compared to standard light crude oils, conventional pipelining isn't adequate for transporting heavy oil and bitumen to refineries without reducing their viscosity. The techniques used for transporting heavy oil and bitumen through pipelines are classified into three as shown in Fig. 6:

(a) Viscosity Reduction [e.g. preheating of the heavy oil and bitumen and subsequent heating of the pipeline, blending and dilution with light hydrocarbons or solvent, emulsification through the formation of an oil-in-water emulsion and lowering the oil's pour point by using pour point depressant (PPD)]

(b) Friction Reduction (e.g. pipeline lubrication through the employment of core-annular flow, drag-reducing additive)

(c) in situ partial upgrading of the heavy crude to supply it with improved viscosity, American Petroleum Institute (API) gravity, and minimised asphaltenes, sulphur and heavy metal content.

4.1.1 Viscosity Issues

One of the foremost important aspects of heavy oils is their viscosity, since the high viscosity of heavy oils directly impacts the recovery and productivity of the crude. Although there is no direct relationship between density and viscosity, a reduction in °API is generally accompanied by an increase in viscosity. Heavy oils display viscosities ranging from a few hundred to tens of millions of centipoises under reservoir conditions. Thus, the transport of heavy oils through pipelines and porous media nearly requires additional energy, and infrequently requires the addition of the heat or diluents to ensure acceptable flow rates.

4.1.2 Partial Upgrading

Upgrading is a heavy oil or bitumen improvement method that uses hydroprocessing to modify the relative proportion of the oil hydrocarbons, making the oil less viscous without altering its refining characteristics. In this process, carbon - carbon bond breaking produces smaller paraffin and olefin molecules, reducing the oil viscosity and making it lighter. Almost always partial upgrading is preferred with regard to total upgrading because the cost of the process and the extension of the upgrading depend on the cost-benefit relation. Hydroprocessing could be a broad term that features hydrocracking, hydrotreating and hydrorefining.

SCWC technology is a thermal cracking process to upgrade extra heavy oils into pipeline transportable synthetic crude oil by using supercritical water (i.e. higher than 374ºC, higher than 22.1 MPa). It is a simple process using only water not using hydrogen or catalyst. It produces liquid products but no solid products. It is an upgrading process utilizing such features of supercritical water. The main product is suitable for pipeline transportation in terms of kinetic viscosity and gravity. Although the product is a thermal cracked product, it is stable enough for long term storage, has good solubility even blends with other crude oils, and exhibits low fouling speed at heat exchangers.Pitch, byproduct, can be utilized as boiler fuel as it can have viscosity low enough for good atomizing at burner nozzle at tempered condition. The pitch can be a binder material for road asphalt by adjusting specifications in terms of penetration and viscosity. SCWC is environmentally friendly as its process is so simple that its footprint is one fourth of the delayed coker process and produces no solid waste such as petroleum coke.

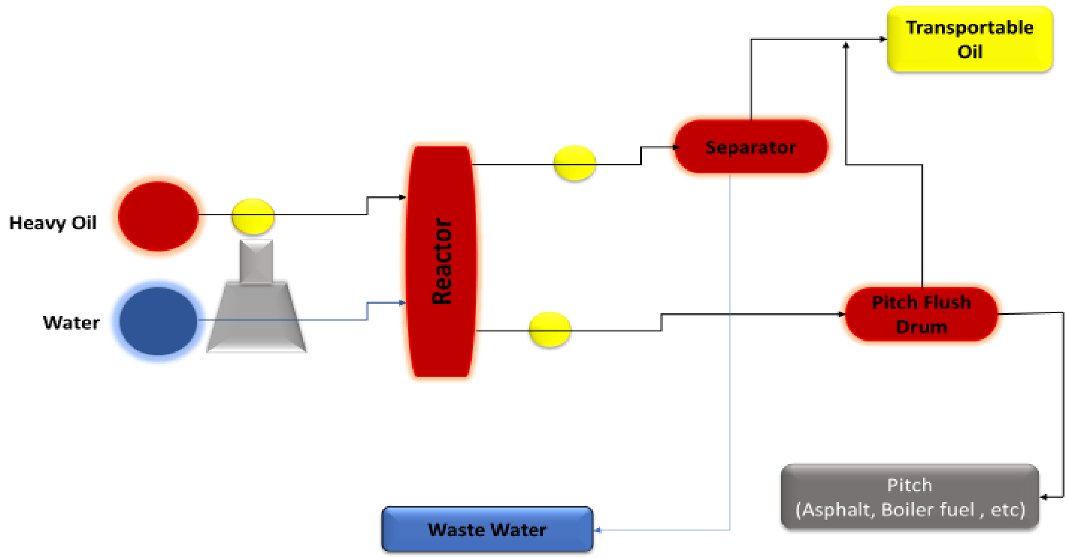

Figure 7: Schematic diagram of SCWC Partial Upgrading

4.1.3 Dilution

High viscosity at reservoir conditions is a major setback to heavy crude oil and bitumen recovery and transportation via pipelines. Thus, blending or dilution of heavy crude oil and bitumen to reduce viscosity is one of the several means to improve transportation via pipelines that is a most commonly used technique in the petroleum industry since the 1930s. The blending fluid or diluents is always less viscous than the heavy crude and bitumen. Generally, it is well known that lower the viscosity of the diluents, the lower is the viscosity of the blended mixture of heavy crude and bitumen. The widely used diluents include condensate from natural gas production, naphtha, kerosene, lighter crude oils, etc. However, the utilization of organic solvents like alcohol, methyl tert-butyl ether, tert-amyl methyl ether has been investigated. The use of those solvents is prompted on the basis of their use in improving the octane number of gasoline. A combination of hydrocarbons and organic solvents with polar group in their molecular structure has shown some effectiveness in viscosity reduction of heavy oil at constant dilution rate. The use of diluents allows the transportation of huge quantity or volume of heavy oil and bitumen. Furthermore, the viscosity of the blended mixture is determined by the dilution rate as well as the viscosities and densities of the heavy crude oil and bitumen and the used diluents. The resulting blend of heavy oil and diluents has lower viscosity and thus it's easier to pump at reduced cost. The dilution of heavy oil and bitumen to reinforce transportation by pipelines requires two pipelines, one for the oil and another for the diluents. The use of diluents to enhance the transportability of heavy crude oil and bitumen in pipelines would be cost-effective, if the diluents are relatively cheap and readily available. The amount of diluents required for heavy crude oil, i.e. the ratio of diluents in the blended mixture, ranges from 0 to 20 %, while for bitumen it is in the range of 25–50 %. Light natural gas condensate (pentane plus or C5) is a low-density and less viscous mixture of hydrocarbon liquids, which is a by-product of natural gas processing. This is because asphaltenes present within the heavy oil are insoluble in alkanes like n-pentane and heptanes, because the condensates are known to be paraffin rich light oil. The mixture of two different oils or petroleum products will result in a product in which the flow properties will be between those of the initial components. Based on this finding, the addition of less viscous crude oils and fractions of distilled petroleum such as condensate, gasoline, kerosene or naphtha to viscous oils has been proposed to reduce the viscosity to acceptable levels for pumping. There is an exponential relationship between the viscosity of the resulting mixture and the volume fraction of diluent, so small fractions of diluents can cause a marked reduction in oil viscosity. Due to the addition of light oils or solvents, the loss of frictional pressure is reduced. The rate of this reduction is bigger in lower temperatures. Limitations to the use of dilution in the transport of heavy oils are imposed by the increasing scarcity of light oils and diluents and their high market values. Diluent reuse may be a way to reduce costs, but it requires a high investment to create and operate an extra pipeline system. Light hydrocarbons and natural gas condensates (C5+), which are a byproduct of natural gas processing, are the most widely used diluents today. An additional problem is the availability of light oils close to the regions of heavy oil production, making the oil mixture even more difficult. The scarcity of light oils and diluents and the high cost of heat generation, combined with the costs caused by environmental and climate specific issues, have discouraged the use of dilution for the movement of heavy and viscous oils. The use of diluents with a high added value, such as kerosene, is generally an expensive choice because an amount of about 20% (for bitumen, this percentage may reach 50%) is needed. Dilution with light oils is less efficient and almost always requires heating the mixture. Even in situations where the viscosity is reduced to acceptable levels for pumping as by the increase in solvent polarity, there is the need for compatibility testing between the oils to prevent solids precipitation, mostly composed of asphaltenes, and the subsequent pipeline blockage, and building a solvent recovery unit, which results in a cost increase.

4.1.4 Heating

Another commonly used method to cut back the high viscosity of heavy oil and bitumen and improve the flowability is effect of temperature. Heating (i.e. increasing temperature) the pipeline causes a rapid reduction in viscosity to lower the resistance of the oil to flow. Therefore, heating is another alternative means of enhancing the flow properties of heavy oil and bitumen. This is because the viscosity of the heavy oils and bitumen is reduced by several orders of magnitude with increasing temperature. This involves preheating the heavy petroleum followed by subsequent heating of the pipeline to enhance its flow. However, heating to extend the temperature of the fluid involves a substantial amount of energy and value also . Other issues include greater internal corrosion problems, because of the rise in temperature. However, heating the pipeline could induce changes within the rheological properties of the oil which can lead to instability in flow. Many numbers of heating stations are required adding to the cost, in addition to heat losses occurring along the pipeline as a result of the low flow of the oil. However, most of the times the pipeline is insulated to maintain an elevated temperature and reduce the heat losses to the surroundings. Additionally, sudden expansion and contraction along the pipeline may induce challenging problems. Consequently, the price of operating the heating as well as the pumping systems over an extended distance from the oil field to the ultimate storage or refinery is on the high side. The method might not be viable for transporting crude oil when it comes to subsea pipelines. Finally, the cooling effect of the encompassing water as well as the earth lowers the efficiency of the technique.

4.1.5 Emulsification of the heavy crude in water

The emulsion of oil and water exists within the hydrocarbon reservoir, well bore, during drilling as well as transportation. This technology is one amongst the most recent means of transporting heavy oil via pipeline in oil-in-water (O/W), water-in-oil (W/O) emulsion or during a double emulsion like oil-in-water-in-oil (O/W/O) and water-in-oil-in water (W/O/W), with the drop sizes in micron range. The formation of oil-in-water emulsion has been an alternate technique of enhancing heavy oil flowability through pipelines. In this technology, the heavy crude oil is emulsified in water and stabilised with the aid of surfactants. The oil become dispersed in water within the sort of droplets with the help of surfactants and a stable oil-in-water emulsion with reduced viscosity is produced. The methods accustomed generate the oil droplets to form the emulsions includes use of devices like dispersing machines, mixing with rotor– stator, colloid mills, high-pressure homogenisers applying high shearing stresses, emulsification by membrane and ultrasonic waves. The different possible emulsions are depicted in Fig 8.

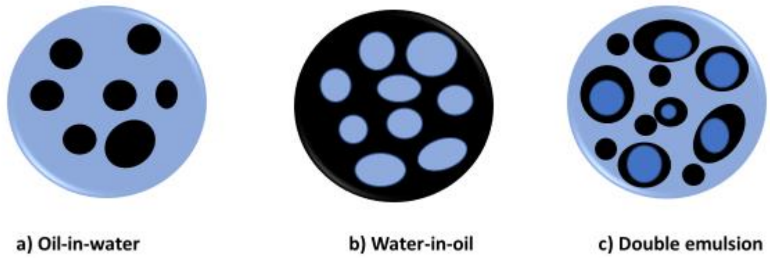

Figure 8: Emulsions

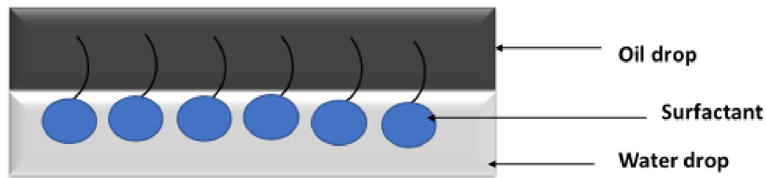

Figure 9: Surfactant-stabilised emulsion

heavy crude oil is a complex mixture of hundreds of thousands of compounds. The asphaltenes act as natural emulsifiers. Other active surface components of crude oil include naphthenic acids, resins, porphyrins, etc. The presence of these component increases the complexity of crude oil emulsion, as the molecules can interact and reorganise at the oil–water interface. In that case, to transport heavy crude using emulsion technology involves three stages such as producing the O/W emulsion, transporting the formed emulsion and separating the oil phase from the water phase. However, recovering the crude oil entails breaking the oil-in-water emulsion.In general, the behaviour of heavy crude oil-in-water emulsion is complex due to the interaction of several components within the system and many other factors mentioned above.

4.1.6 Pour point reduction

Heavy crude oils have been described as a colloidal suspension consisting of solute asphaltenes and a liquid phase maltenes, that is, saturates, aromatics and resins. The precipitation and aggregation of the asphaltene macromolecules in the oil contribute greatly to its high viscosity and density, resulting in its high resistance to flow in pipelines. Therefore, suppressing this effect through the use of pour point depressants will help improve the oil flow properties. The pour point of the oil is the lowest temperature at which it ceases to flow and loses its flow properties. For instance, it's extremely difficult to transport via pipeline waxy oil in cold conditions. This is because decreasing temperature causes crystal growth which prevents the molecules of the oil from flowing. The crystallisation depends on climate, oil composition, temperature and pressure during transportation. There are several methods to minimise the reason behind wax and asphaltenes deposition, and therefore the use of polymeric inhibitor is taken into account a viable alternative. The addition of copolymers like polyacrylates, polymethacrylate, poly (ethylene-co-vinyl acetate), methacrylate, etc. inhibits the deposition phenomenon and stabilises transportation. The complex nature of heavy oil creates many challenges during its transportation through long distance, especially when using pipelines. To overcome such problem of wax crystal formation as an interlocking network of fine sheets that block pipelines, pour point depressants (PPD), which contains oil-soluble long-chain alkyl group and a polar moiety in the molecular structure, is used. The long-chain alkyl group is inserted into the wax crystal and therefore the polar moiety exists on the wax surface and reduces wax crystal size. The PPD in most cases possesses highly polar functional groups.

4.1.6 Core-annular flow

Core annular flow is a technology based on the formation of a flow pattern in which the oil is transported in the central region of the tube, surrounded by a thin annular aqueous film formed near the wall, lubricating the flow. This flow pattern shows great stability if the liquids have similar densities, are immiscible and do not form emulsions. The mechanisms of hydrodynamic destabilization of the annular flow originate from capillary forces and inertia (the difference between the interfacial velocity of the fluids), and are evidenced by the deformation of the liquid-liquid interface. Capillary instability is a consequence of surface tension and of the density difference between the liquids.The accumulation of oil at the pipe walls is one of the main problems encountered in implementing core annular flow - the gradual adherence of oil can cause a blockage in the pipe section, preventing flow.

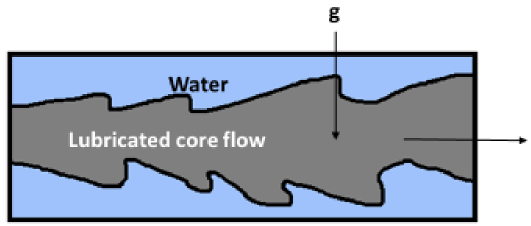

Figure 10: Core Annular Flow Sketch

4.2 Solid Precipitation

Solid precipitation has been a serious issue in the oil industry. The reservoir fluid production alters the storage mechanism which may cause solid deposition. These deposits can cause formation damage and in situ plugging which result in the loss of reservoir permeability and degradation of the porous media. The deposition of the solids on the surface of the media may affect the wettability and decrease the transmissivity. The solid deposition problem is frequently observed in the wellbore and well tubing. It may plug wells, increasing the fluid pressure gradient which can result in significant reduction in well productivity. It can also cause operation problems in the subsurface and surface equipment. In these cases, costly well workovers or other production treatments may be required.

4.2.1 Asphaltene

Asphaltenes are high molecular weight hydrocarbons, defined as a class of petroleum that is insoluble in light alkanes but soluble in toluene or dichloromethane. Asphaltenes cause flow assurance problems in conventional / non-conventional oil production. These effects include:

- Pipe flow area reduction
- Alteration of wettability
- Blockage of pipelines
- Efficiency reduction of the production equipment

These effects are related to the asphaltenes precipitation due to decreased solubility in the produced fluid. This may occur ataltering pressure-temperature conditions. Heavy oils are known to have high asphaltenes content, but as asphaltene solubility is proportional to the molecular weight of the components, they are less vulnerable to asphaltene precipitation than lighter fluids. However, the asphaltene has a tendency to aggregate, making the oil very viscous. A common flow assurance strategy is diluting the heavy crude with lighter hydrocarbon and injection fluid or another well-stream, thus reducing viscosity and friction pressure loss. This will change the composition of the fluid, and asphaltene may be destabilized and precipitate. Asphaltenes may precipitate in heavy oil pipelines depending on pressure and temperature conditions. So it is necessary to consider these issues in the flowline design, especially where heavy oil is blended with lighter diluents.

4.2.2 Hydrates

Hydrates are crystals that formed when water and gas are combined in a low temperature and high-pressure conditions. A mixture of oil, gas, water and sand is obtained during the production from the reservoir. If the pressure is high enough and the temperature low enough, water and gas are combined and form hydrates.Hydrates are solids in crystal form. Hydrate layer formation can reduce the diameter, ultimately block the pipeline and adhere the flow. Hydrates can plug the downhole tubing, tree-manifold piping, flowlines and risers. The plugs can be difficult to locate and remove leading to significant losses in production and revenues.

Formation of hydrates can be prevented by :

1. Chemical injection: Depending on the reservoir fluids the injection chemical can be
-Methanol or Mono Ethylene glycol (MEG) for gas and gas/condensate wells.
-Kinetic gas hydrate inhibitors for low water production rates
2. Thermal insulation: Thermal insulation acts in preventing the rapid cool-down during shut downs providing thus time for the operator to take remedial action.Thermal insulation of subsea infrastructure results in maintaining the temperature of the flow above the hydrate formation temperature.
3. Lower the pressure: Operating pipelines at lower pressure especially during shut-in conditions.
4. Removal of water: It is possible to prevent the formation of hydrates by removing the water from the flow before the the fluid reaches temperature and pressure conditions that hydrates are formed.

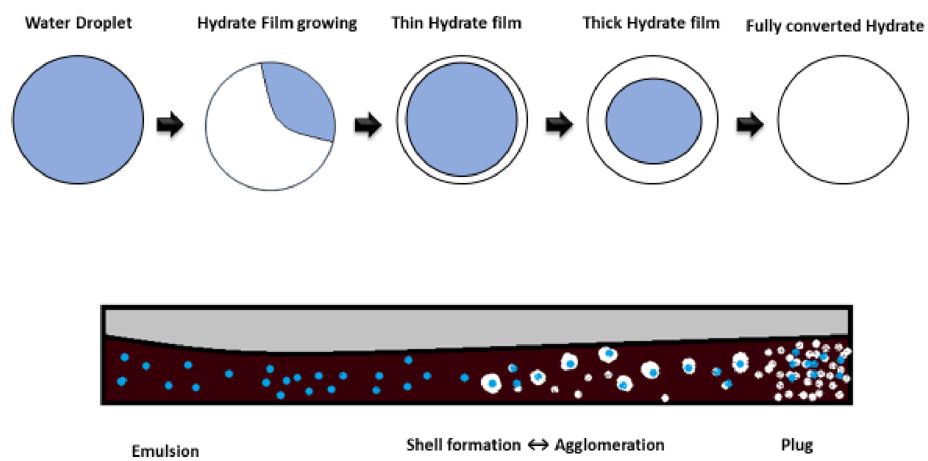

Figure 11: Hydrate Formation

4.2.3 Scaling

The precipitation in reservoir and production systems are known to be a problem when recovering heavy oil. These issues may escalate when sea water is injected into the reservoir as it contains salt, which alters the salt concentrations and pH levels of the liquids. In conventional reservoirs, this is normally prevented by the injection of an inhibitor but in non-conventional reservoirs, low mobility of heavy oil may prevent this. The potential impact is greatly dependent on the conditions and fluid composition of each reservoir.

4.2.4 Wax

Wax deposition causes flow adherence in the production of many conventional oil fields. This is caused by precipitation of paraffin in well tubing or flowlines. Heavy oils, however, are in most cases highly biodegraded, minimizing paraffinic content. For this reason, wax is largely a non-issue in heavy oil production.

4.3 Pumps

Pumps are necessary for the transportation of oil from wellsite to central facilities, between upgrading installations and for long-range transport to other distribution center.

Three parameters are critical in the selection of heavy oil pumps are Oil viscosity, Solids production and presence of gas in produced liquids.

There are two common categories of oil pumps used in the oil industry: positive displacement pumps and dynamic pumps. Viscosity affects the performance of all pumps, but in different manners. With a positive displacement pump, oil up 100’000 cP viscosity may theoretically be pumped, though the realistic limit for pipeline transportation of oil is at ~1000 cP. Dynamic pumps generally become unattractive for oil viscosities above 100 cP. For this reason, positive displacement pumps are usually preferred for heavy oil applications. Heavy oil may have significant solids content, and this must be considered when selection of pump is done. The suspended solids increase the viscosity of the fluid and may erode it. This may reduce the lifetime of a pump down to a few months. Effects may be mitigated by either installing sand removers upstream of the pump, or select a low velocity pump such as twin-screw pumps. High viscosity makes separation of heavy oil difficult, and some associated gas often remains in the stream. This may significantly impair the performance of conventional pumps.

4.4 Offshore

Offshore heavy oil fields face extra challenges compared to onshore production. The offshore production has additional costs and platform space constraints which makes the traditional heavy oil production methods like steam injection unsuitable. For this reason, offshore heavy oil recovery is limited to cold production, with some secondary recovery methods like water and gas injection applied. This comes with consequences for the production processes like low temperature at the wellhead will significantly increase viscosity and limit flow rates.Also upgradation in artificial lift technology is inevitable. This is even more important for heavy oil fields, as the onshore production boosting techniques are not applicable for offshore production plants. Gas lift completion shows better cost ratio than ESPs in conventional deepwater fields. For heavy crudes, the effect of gas lift is limited due to high viscosity, but submersible pumps have a high rate of failure. The production of heavy viscous oils may significantly change the water-oil ratio over the life of the well. This has the potential to both boost and limit flow rates. If an oil-in water emulsion or dispersion is achieved, this will reduce the pressure drop in a flowline. However, shear forces from pumps or constraints may cause the emulsion to revert to a water-in-oil emulsion, which will have a greater viscosity than the crude. The emulsions may cause processing problems, due to struggle of the separator to separate the phases. The chemical consumption rates for heavy oil-water emulsions is very high, so injection of a demulsifying agent into the production stream results to be economically devasting. Study of emulsion mechanisms of a heavy oil project is evitable in order to finalise the correct flow assurance strategies. The processing utilities are most crucial area for development of offshore heavy oil projects due to the limited platform capacity and subsea technology development. Developments in technologies are generally done for offshore production plants. These strategies are not viable for offshore.

V. CONCLUSIONS

For the increasing exploitation of heavy oil and bitumen, it is necessary to develop technology to aid in their transportation through pipelines. In this review paper, the technologies used to enhance the transportation of heavy crude oil and bitumen through pipelines was explored. Each of the three categories of methods employed to reduce viscosity and pressure drop to aid pipeline transportation of heavy crude oil has been presented along with their advantages and disadvantages. The techniques employed take into consideration the properties of the oil, regional logistics between the well-head and the refining site, operational concern, transport distance, cost, environmental concerns and the legislation. However, the present strategy in the petroleum industry is to integrate in situ upgrading to thermal enhanced oil recovery methods because of the cost, environment and energy effectiveness it offers.

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